

Monolithically Integrated Parallel Amplifiers Structure for Filter-free Wavelength Conversion

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Introduction: Wavelength conversion will be a key feature in WDM optical networks. Wavelength converters based on the cross-gain-modulation (XGM) of a semiconductor optical amplifier (SOA) have several attractive features such as simple implementation, large tolerance for input signal power, and polarization insensitiveness. XGM in the co-propagative mode, where a input signal and a CW light propagate to the same direction, offers higher conversion speed than that in the counter-propagative mode. However, an optical filter is required for the co-propagative mode to reject the input signal. In the case of wavelength tunable conversion, the response time of such filters may limit the system performance, and therefore, filter-free operation is desirable. In this work, we report the first demonstration of filter-free wavelength conversion using XGM in the co-propagative mode using newly developed monolithically integrated parallel amplifiers structure (PAS). Power penalty as low as 0.9 dB was achieved for the worst case, i.e., when the signal wavelength coincides with the CW wavelength.

Design and Fabrication of the device: Figure 1 shows the photograph of the fabricated PAS. The PAS comprises two polarization insensitive SOAs and two multi-mode interference couplers, and was fabricated by butt-coupling the high-mesa and buried waveguides [1]. Tensile-strained bulk InGaAsP was utilized for the SOA active layer. Each SOA has a 0.2- μm -thick 0.1%-tensile-strained active layer and a 0.1- μm -thick InGaAsP guiding layer ($\lambda_g = 1.2 \mu\text{m}$). The fabrication process is briefly as follows: after SOA active layer was growth, 0.5- μm -thick InGaAsP core ($\lambda_g = 1.05 \mu\text{m}$) and 1.0- μm -thick InP cladding layer were butt-jointed. Next, the SOA stripe was dry etched using CH_4 reactive ion etching and embedded by a p-n blocking layer and p-doped InP cladding layer. At the same time, a p-n blocking layer and p-doped InP cladding layer were also grown over the passive region. Then, the p-n blocking layer and p-doped InP cladding layer were removed for the passive region to reduce propagation loss of the passive waveguide. Finally, high-mesa passive waveguides composing Mach-Zehnder interferometer were fabricated by using $\text{Br}_2\text{-N}_2$ reactive beam etching [2]. Propagation loss of the high-mesa passive waveguide was about 5 dB/cm. PAS enables the spatial separation of the signal and CW light, resulting in filter-free wavelength conversion using XGM even in the co-propagative mode. Figures 2(a), (b) show cross-sectional views of the high-mesa passive waveguide and buried SOA, respectively. Figure 2(c) shows the interface between high-mesa passive waveguide and SOA. Waveguides with completely different structures are well jointed. The coupling loss between the SOA and passive regions is about 1 dB including the active to passive coupling loss and the high-mesa to buried coupling loss. SOA length is 900 μm , and total chip size is 4.5 mm x 0.5 mm.

Experiment: Wavelength conversion experiments were performed in the co-propagative mode. The PAS was set to operate in the cross state by adjusting the injection current of the two SOAs. Input signal with wavelength of 1556.7 nm was modulated by 10 Gb/s NRZ signal. Figure 3(a) shows the eye diagram. The CW wavelength was set to the same wavelength as the input signal to investigate the worst case in filter-free wavelength conversion. The input powers of the signal and CW light were 7.4 and 12.5 dBm, respectively. Figure 3(b) shows the eye diagram of the converted signal. Clear eye opening is observed. The corresponding bit-error-rate characteristics are shown in Figure 4. The power penalty of 0.9 dB was obtained compared to back-to-back.

Summary: We have developed a monolithically integrated parallel amplifiers structure (PAS), and have achieved a filter-free, co-propagative wavelength conversion using the fabricated PAS.

References: [1] H. Ishii et al., IEEE P. T. L. vol.11, p242 (1999) [2] S. Oku et al., Journal of Electronic Materials, vol.25 p.585 (1996)

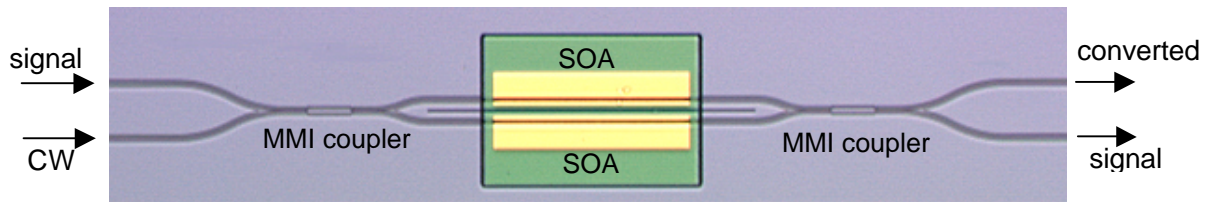
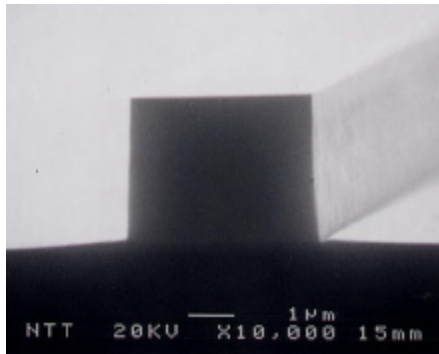
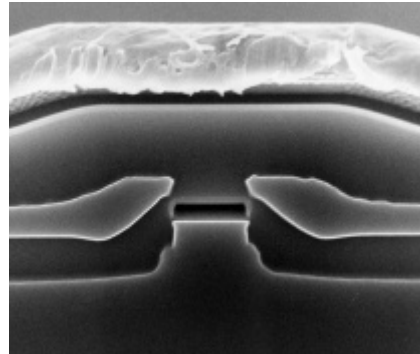


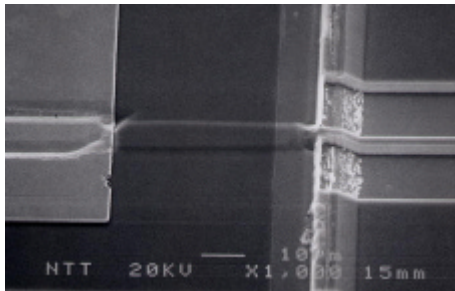
Figure 1. Photograph of the fabricated Parallel Amplifier Structure (PAS).



(a) Cross-sectional view of high-mesa passive waveguide.

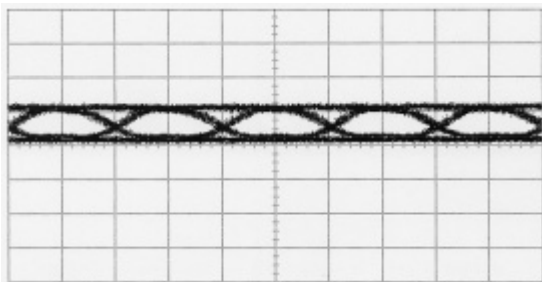


(b) Cross-sectional view of buried SOA.

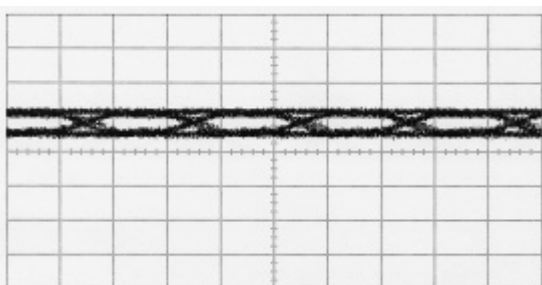


(c) Interface between high-mesa waveguide and buried SOA.

Figure 2. Scanning electron microscope image of the fabricated device.



(a) input waveform



(b) output waveform for conversion to the same wavelength as input signal

Figure 3. Eye pattern of the input and converted signal.

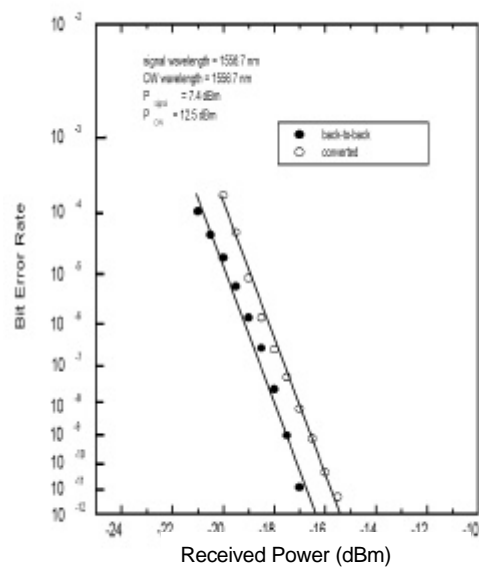


Figure 4. BER characteristics for wavelength conversion to same wavelength as the input signal.